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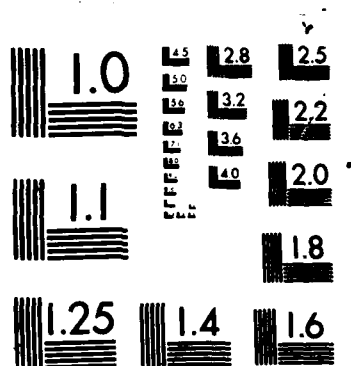
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<p>Robotics offers an ideal test bed for adaptive control algorithms. During the period of this grant we have investigated the use of adaptive methods in generating suitable grasps using robotic hands. We have given a mathematically natural description of compliance and investigated the adaptive control of compliance.</p>					
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Summary

This final report covers the 14-month period May 1, 1985, to June 30, 1986. During this period one Ph.D. student completed his work with partial support of this contract and two papers dealing with applications of adaptive control were written. In one of these the important problem of compliance control, as is commonly used in robotics, is addressed and developed in such a way as to make the mathematical issues clear. In a second paper, the problem of visual tracking is addressed and a new iterative algorithm is proposed for the solution of an estimation problem.

Introduction

The control of the grasping of irregularly shaped objects is a situation which obviously calls for a certain level of adaptation. The parameters to be dealt with in an adaptive way include the size, shape, and weight of the object being manipulated. Key parameters are summarized by the compliance of the grasping mechanism.

In our paper [1] we addressed the problem of characterizing the rotational and translational stiffness of a system. This is a difficult problem because of the coupling between rotational and translational motions which occurs due to a lack of a canonical choice for the center of rotation. We give a natural description of the stiffness matrix by "dividing out" the choice of coordinates.

In [2] we present an iterative algorithm for the computation of motion parameters which characterize the motion in the image plane, given a sequence of contours which change in time due to motion in space. Our method is based on the observation due to Waxman and Ullman (1985)¹ that the second-order polynomial approximation of optical flow in the

¹A.M. Waxman and S. Ullman, "Surface Structure and 3-D Motion from Image Flow: A Kinematic Analysis," *Int. Journal of Robotics Research* 4, 205-217, 1985.

image coordinates provides sufficient information for 3-D motion computation. The use of an explicit flow model enables us to improve normal flow estimates through an iterative process. The algorithm has been tested on the synthetic time-varying images. The optical flows recovered from this scheme are accurate enough to be used for 3-D structure and motion computation.

In his thesis [3] Tony Bloch considers the subject of total least squares. In this formulation of least squares the uncertainty of the range value is coupled to an uncertainty in the domain. For example, it is the fitting of a straight line to a family of points (x_i, y_i) $i = 1, 2, \dots, n$ whereby one minimizes the sum of the squares of the distances from the points to the line. This leads to a more complex algorithm than the usual least squares algorithm. Its structure is investigated in this thesis and related to Hamiltonian dynamics.

Publications

- [1] R. W. Brockett and Josip Loncaric, "The Geometry of Compliance Programming," in *Theory and Applications of Nonlinear Control Systems*, (C. Byrnes and A. Ljung, eds.), Elsevier, 1986.
- [2] K. Wohn, J. Wu, and R. W. Brockett, "A Contour-Based Recovery of Optical Flows by Iterative Improvement," *SPIE Visual Information Processing*, Vol. 707, pp. 10-16, 1986.
- [3] Anthony Bloch, *Completely Integrable Hamiltonian Systems and Total Least Squares Estimation*, Ph.D. Thesis, Harvard University, September 1985.

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